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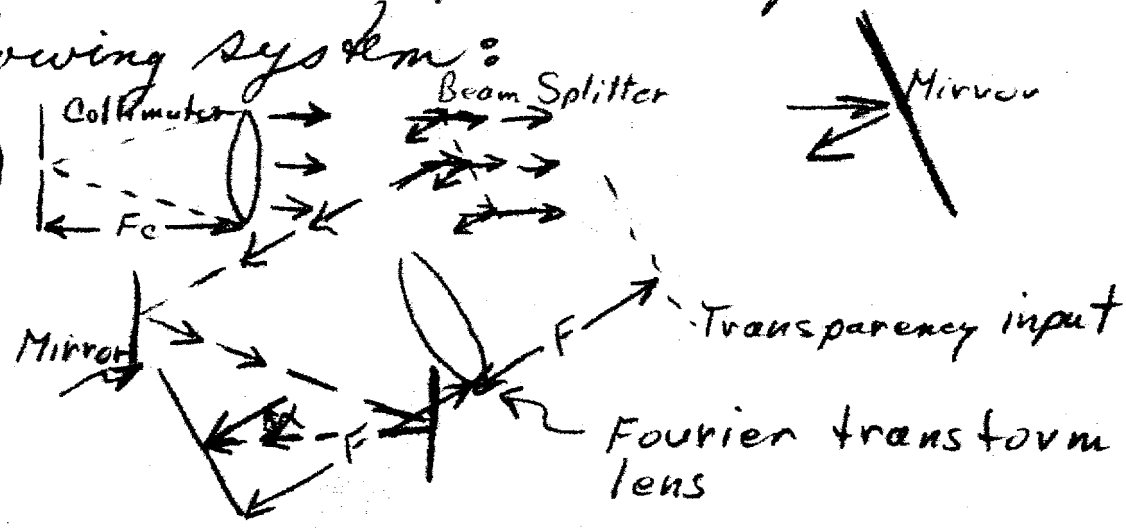
Student's Name [redacted] April 27, 1970 STAT

Subject Instructor's Name

10:15 am – 12:15 pm tutorial session – see notes of subject in STAT [redacted] 22 01201 - 7720-1 concerned with coherent image processing and holographic target detection filtering.

1 P.m. to 6 pm Commencement of laboratory work on the interferometer. Initial objectives are to set up and align the following system:



This system is described in the tutorial notes. Our objective during this p.m. session was to select the components of the system to obtain desired

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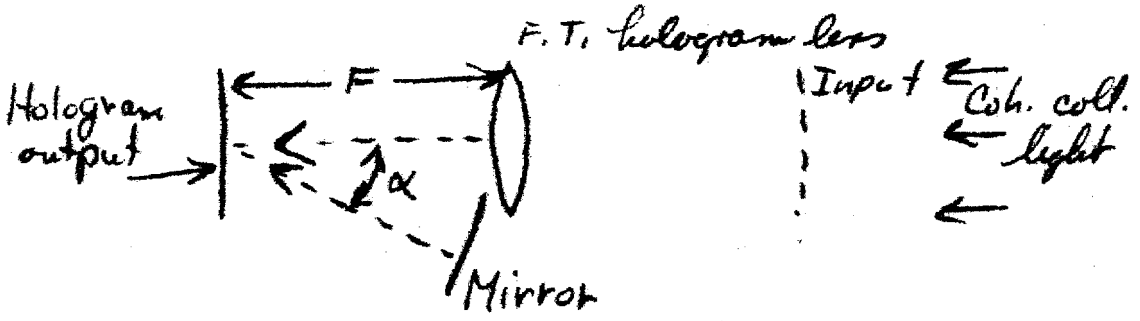
response characteristics.

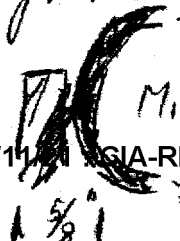
1. Must select lens focal length so that angle α can be within tolerances of required interference fringes (carrier wave frequency) of hologram. Note



The longer F is, the smaller we can get α. — Using Schneider Symmar lens, F = 300 mm f/5.6

F = 500 mm with removal of one element.

For 500 mm focal length configuration we could reduce α to about 5-6°. Mirror housing forces us to keep mirror 5/8" from edge of blocking component.



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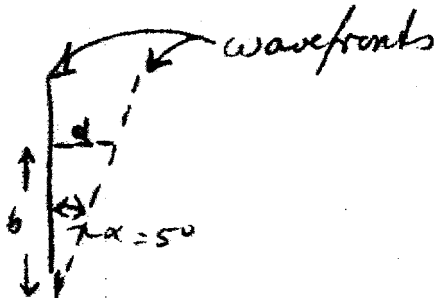
Amount that places the mirror at the edge of the format would allow us to minimize the angle.

2. For $\alpha = 5^\circ$, what is the carrier wave frequency?



$\tan\alpha = d/b$

for $b = 1\,mm$, $d = n\lambda$, n will be the # of cycles/mm.

$n\lambda = b \tan\alpha$

$\tan 5^\circ = 0.0875$

$\lambda = 6.328 \times 10^{-4}\,mm$

$$n = \frac{0.0875}{6.33} 10^4 = 138\ \text{l/mm}$$

---

3. What angle do we need? We are considering the use of the 300 mm, f/5.6 Symmar lens in the coherent processor.

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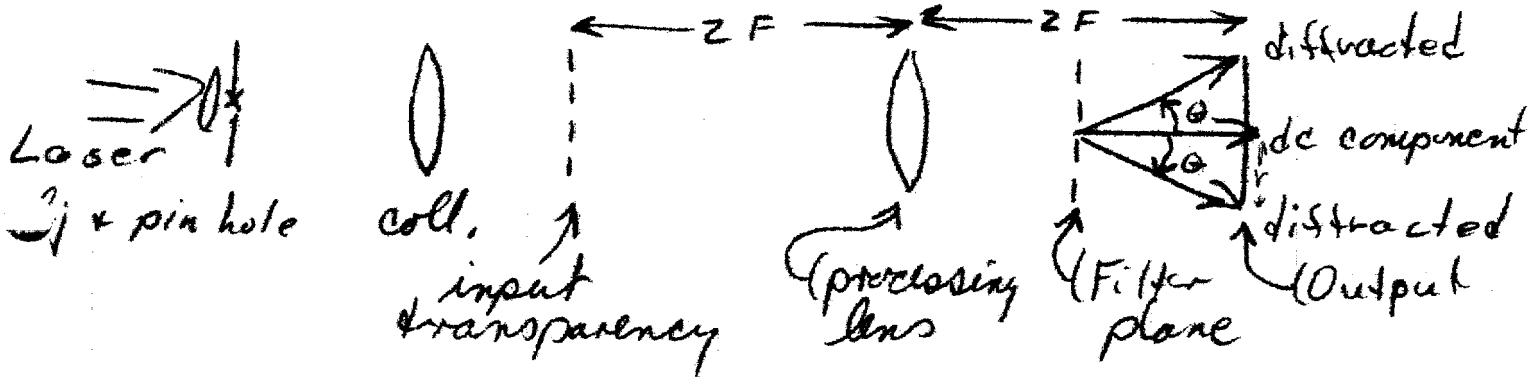
The angle α specifies the diffraction angle in the coherent processor. That is

Coh. processor system diagram



The diffraction angle θ is given by

$$\tan\theta = \frac{r}{F} = \lambda\omega$$

where r is the distance of diff. at the output plane

$\lambda = 6328\ \text{Å}$

ω is the carrier wave frequency.

$F = 300$ mm

Assume a 25 mm separation is desired in the output, $\therefore r = 25$ mm $\quad \tan\theta = r/F = 0.0833$

$$\theta = 4^\circ 46'$$

Therefore what is the corresponding α for the

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interferometer. First, the carrier freq. ω is $\frac{V}{\lambda F} = \frac{0.0833}{6.33 \times 10^{-4}} = 132$ cy/mm

This corresponds very closely with the 138 cy/mm that we get for the 5° angle in the interferometer.

Concl. 1. Working at $\alpha = 5°$ for $F = 500$ mm is sufficient for the detection system, where at $F = 300$ mm, $\omega \cong 4\frac{1}{2}°$.

---

2. According to the above we can use the 500 mm lens in the interferometer & the 300 mm lens in the coh. processor.

---

3. We should try to get larger format beam splitters & mirrors for the interferometer for future activity at larger formats.

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4. We can now go ahead and set system interferometer for Fresnel hologram fabrication (see TM 70-1 referenced above). Align all components using cross-hair reference and Boys point alignment. This to be performed tomorrow (28 April, 1970).

Objectives 28 April 70

1. Set-up of interferometer with critical alignment & optimization of intensity —
2. Fabrication of Fresnel holograms to demonstrate Hologram Technology
3. Set-up interferometer for F.T. holograms upon completion of satisfactory Fresnel holograms.

STAT Personnel [redacted]

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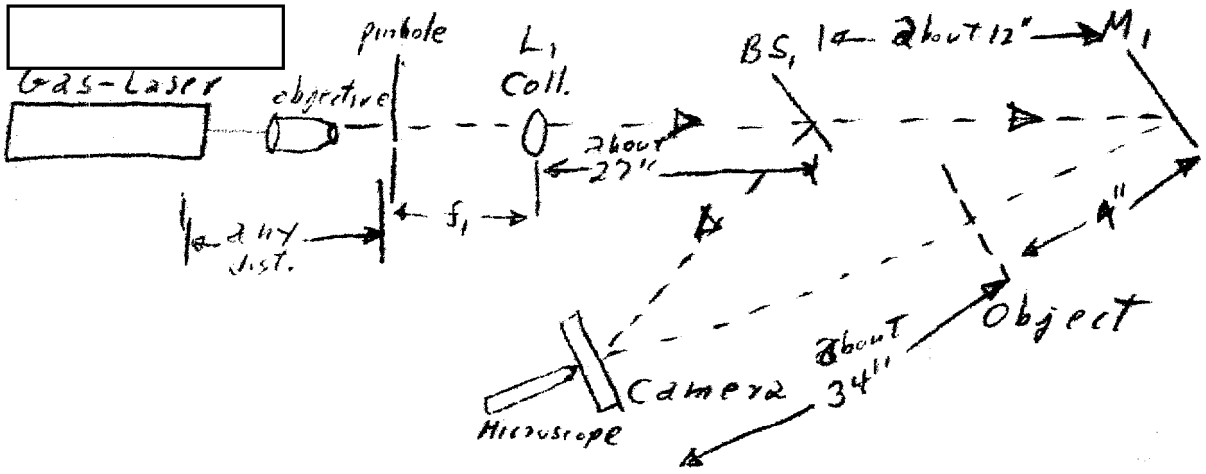
Student Name [redacted] Date April 28, 1970

Subject [redacted] STAT

Fresnel Holograms

25X1 [redacted]



Equipment

STAT Laser - [redacted] Gas Laser

STAT Objective - [redacted] 20x

Pinhole - 10μ

25X1 L_1 - [redacted] Lens 446 mm f/11.8

BS_1 - 40/40

M_1 - Front Surface mirror

25X1 Camera - [redacted]

Microscope - [redacted]

Alignment using crosshair & Target

① Using Target - align the laser for height by moving the Target from one end of the bench to the other

② Set Target at the far end of the bench for x-y position and do not move

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(3) Insert the objective and set up the cross hair (note the crosshair should not be moved after this step) - align the objective

(4) Insert the pinhole & focus the objective for maximum light

(5) Insert coll. lens & align with the crosshair & target that haven't been moved.

(6) Insert beam splitter with alignment target moved to the camera plane.

(7) Insert M_1 so that the reflected beam overlaps the reference beam in the film plane

(8) Insert object plane.

Print here of interferometer

Print here of interferometer

Fresnel Hologram System

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Fresnel Holograms of several scenes were made.

STAT [redacted] developed the film and good exposures were found to be 8 sec.

Prints of the holograms will be made and inserted below

Fresnel Hologram

Reconstruction

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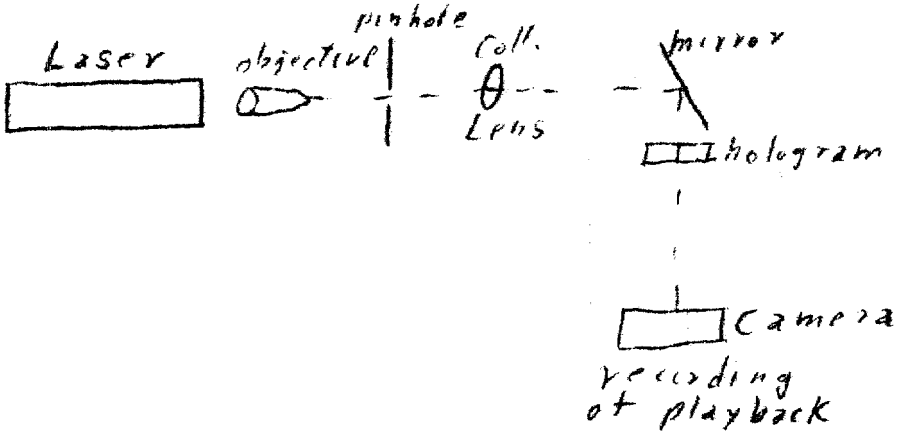
Playback of Fresnel Holograms

On the 28th a hologram of a graph was made (Eye Sensitivity (Luminosity Factors)) graph

A playback of the hologram was made on pan-x with a good exposure of 1min.

The playback system was made up of the taking system with a mirror inserted after the coll. lens



Playback System

Result on page 10

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Playback Result

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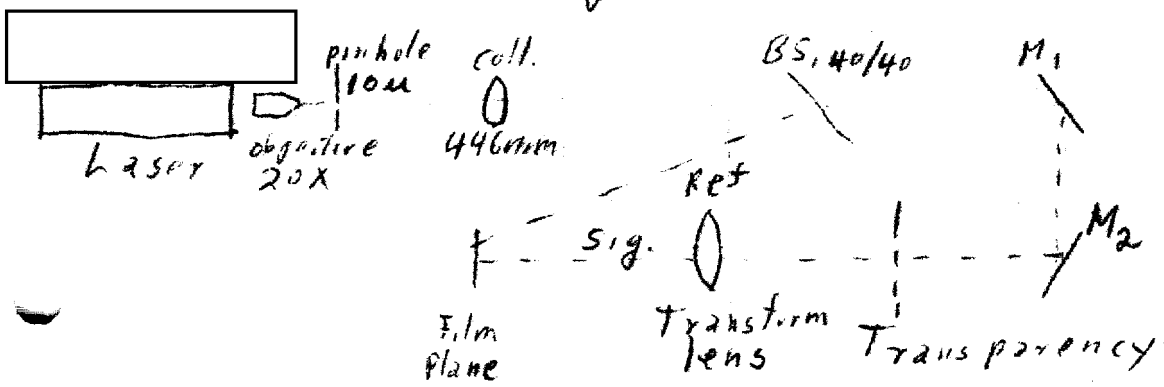
Fourier Transform Hologram

A Fourier Transform hologram system of the following format was set up.



The angle between the ref. & sig is too large for the frequency wanted in the film plane (see page 4) 138 l/mm. The mount for the Transform lens is the limiting factor for this system. The system shown on page 2 should have no problem with angles. John C. will modify the camera mount so no clipping will be present when the Ref. beam comes in at the needed angle.

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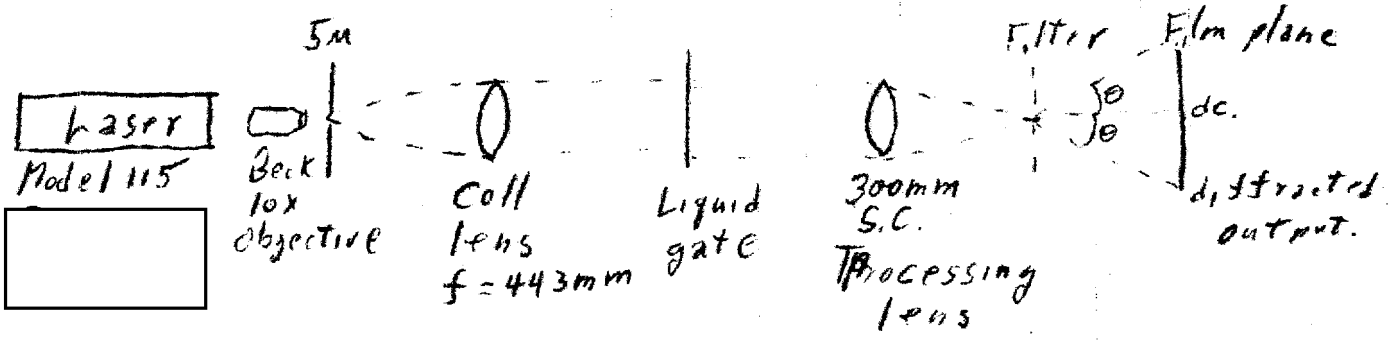
Coherent Processor System



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The above system was aligned by John C. and Dick P. as follows:

(1) Using the alignment targets the laser was aligned on the Tech/ops bench. The mirrors were set for maximum output.

(2) The 10x objective was inserted and aligned

(3) The 5m pinhole was aligned.

(4) The collimating lens was cleaned and aligned and set at 1f in front of the pinhole.

(5) Since the main objective at this time was to set the bench up the liquid gate was not set on the bench.

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(5) Continued:

When the liquid gate is set on the bench the plates should be perpendicular to the optical axis or at enough of an angle so that the reflections do not interfer with the imagery

(6) The processing ~~was~~ lens was cleaned and aligned on the bench

(7) The Filter plane will be inserted when the bench is operational which should be ~~the~~ next week or the next trip.

(8) The film plane or camera has to be mounted off axis. This will be found by John C. and the mounting plate will be drilled.

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a.m.

Topics discussed -

Fringe effects within hologram format.

1) A concentric, very Fresnel type pattern exists centered on the format of the interferometer. This could arise from some aperture within the system - we'll have to ensure it does not introduce noise to the detection output.

2) Interference fringes are present at right angles to the hologram carrier waves. These are probably due to a double reflection of the transform function - as in the object plane where the liquid gate is located.

Liquid gating

1) Best to avoid this if possible. Liquid gates are not conducive to an operational system - reduce flexibility - can be important in optical image restoration but not necessarily so in target detection. Intersurface reflections may arise from this component.

2) The phase component of the filter is very important in the target detection process. It is estimated (see Tsujiuchi) that the phase component accounts for about 80% of the detection process. We will have to get into this discussion later when we have filters as the subject matter.

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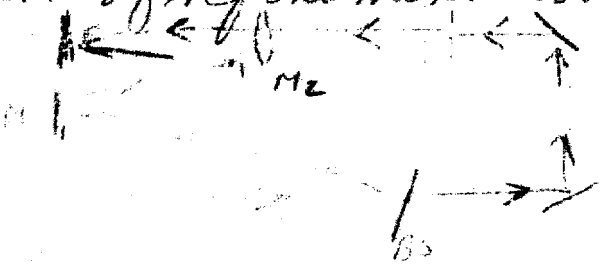
a. m. cont'd.

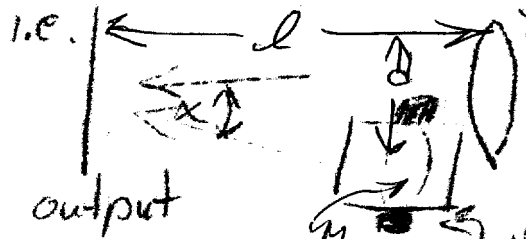
Holographic Interferometer Refinements

We should look into the reference beam angle limitations to reduce the angle to about 4° if possible. It is necessary to maintain a carrier frequency that is sufficiently high to give format separation and the readout - but if this frequency is too high then we will not have good image contrast because of the lower film contrast response.

The reference wave configuration at start of refinement was



The mirror M_2 was separated because of its mounting chassis by a distance of several inches from the transform lens.



$\alpha \simeq 9°$

this chassis and the gimbal mount preclude a small angle α between the two beams.

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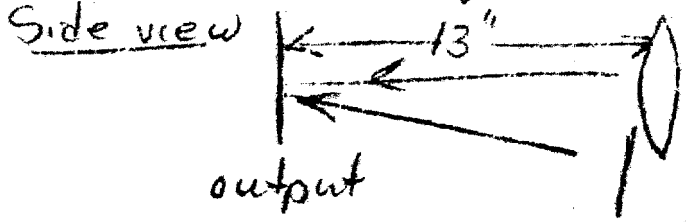
To resolve this:—

1. Altered mount & position of mirror M_2 to be below the interferometer transform lens. This gave us an increase in distance l by 1" — to 13".



$l = 13"$

$d = 1.5$ & $1.75"$

d is limited because of the gimbal mount.

a) for $d = 1.5"$ $\quad \frac{d}{l} = \frac{1.5}{13} = 0.116$

$\tan x = 0.116 \quad x = 6°37'$ this is better than the 9°

fringe freq. $n = \frac{\tan x}{\lambda} = 184$ l/mm

b) for $d = 1.75"$ $\quad d/l = \frac{1.75}{13} = 0.1346 = \tan x$

$x = 7°40'$

$n = 214$ l/mm

so the fringe freq. is between 180 — 215 l/m

Images of F.T. hologram of triangle taken. Best exp 1 - 2 sec.
Exp taken 1 - 8 sec.

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pm

2. The second refinement to minimize α was to remake the gimbal mount and place a 1/20 λ front surface mirror in the same position as M_2 — but with $d = 1 - 1.25''$.

at $d = 1''$ $\tan \alpha = 1/13 = 0.077$

$\alpha = 4^\circ 25'$

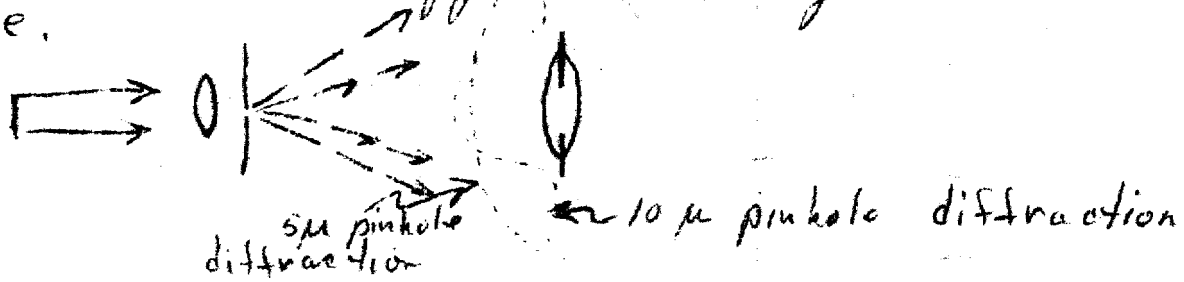
$n = 122$ l/mm This is good!

F. T. holograms of triangle recorded with this set-up.

Hologram detection filters from #1 & #2 will be set-up and tested in the coherent processor.

Coherent Processor alteration

Some refinement of the coherent processor was performed because there was only a 5 μ pinhole for illumination. This caused a severe loss of light — not only because of its aperture area but also from its wide diffraction angle — i.e.



hold the loss of light from the 5 μ pinhole.

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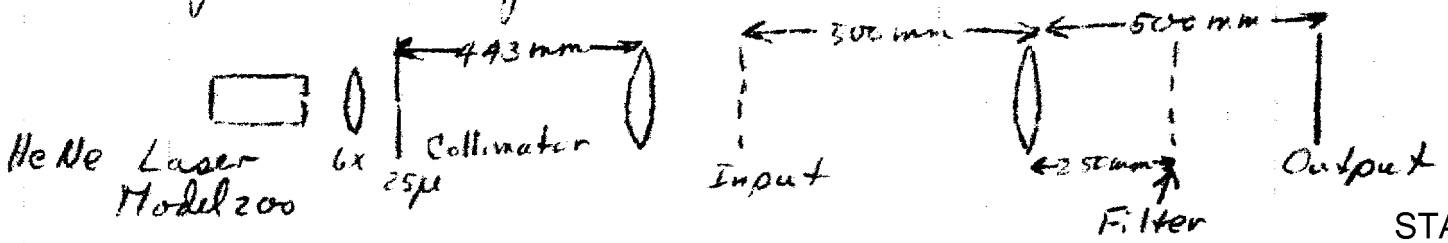
Second problem the Model 152 Spectra Physics laser which had been operating at a power far below its rated output, stopped lasing. We replaced it with a Model 200 Spectra Physics He Ne laser — same wavelength at 0.6328 μm..

Also we altered the processing lens by removing the back element of the Schneider Symmar — changing its focal length from 300 to 500 mm.! This is the same lens configuration as is used on the interferometer.

System Diagram



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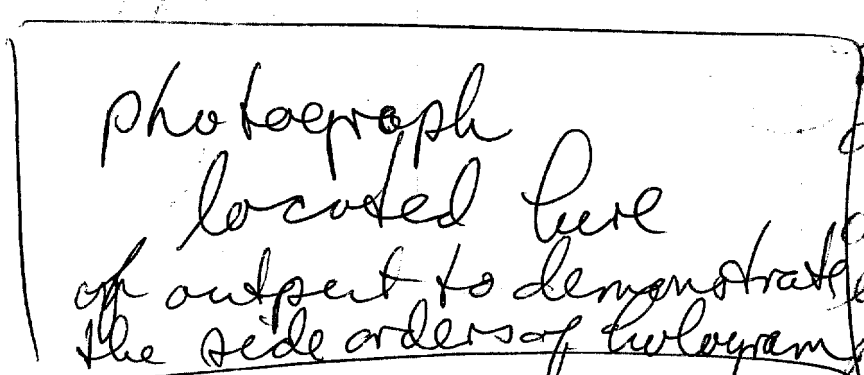
At the close of 6 May we [redacted] placed the filters noted on p. 18 — the lower frequency modulation referred to as #2 — into the system. Objective was to ensure refracted components of hologram were occurring at the output. The result is: —



Note the off axis diffracted outputs — encircled in the

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It is emphasized that only rough alignment procedures were used to obtain the ~~Fresnel~~ Fraunhofer photograph of the hologram filtered output. A refinement is to be conducted tomorrow a.m..

---

a.m. May 7, 1970

Points to look at

1) Simplify target by using only one triangle in the format, aligned with the hologram filter.
2) Align the target - and the filter with extreme care. Final refinement of alignment is obtained by looking at the output and optimizing it*.
3) Photograph filtered outputs and determine if detection process is occurring. Also test the different filter exposures.

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* The optimization and alignment procedures for the filtering operation are noted on p. 24.

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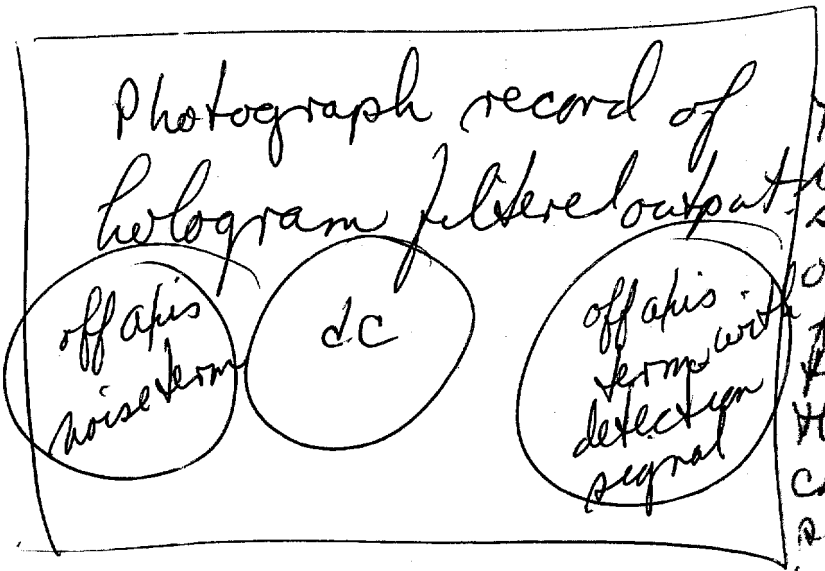
The previous directives (fm p 20) were followed. We simplified the target and carefully aligned the hologram filter (#2 fm p. 18). This filter had a fringe frequency of about 122 ℓ/mm.

Filter used

1) Hologram negative exposure
2) About 122 ℓ/mm fringe freq.
3) Formed from a 50/50 beam splitter.
4) Of low frequency (obvious when we see it) does not extend far from the dc region, especially when compared to the diff. pattern of the input).
5) A 4 sec. exposure hologram

Results using processor sketched on p. 19



to the right

The detected term is a correlation signal between object input and filter. The higher the central peak, the higher the correlation. This shows an output where the peak is slightly higher than the side terms.

roll
A 3000
2c exp.

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Move the detection signal to the right, the dc center and noise to left

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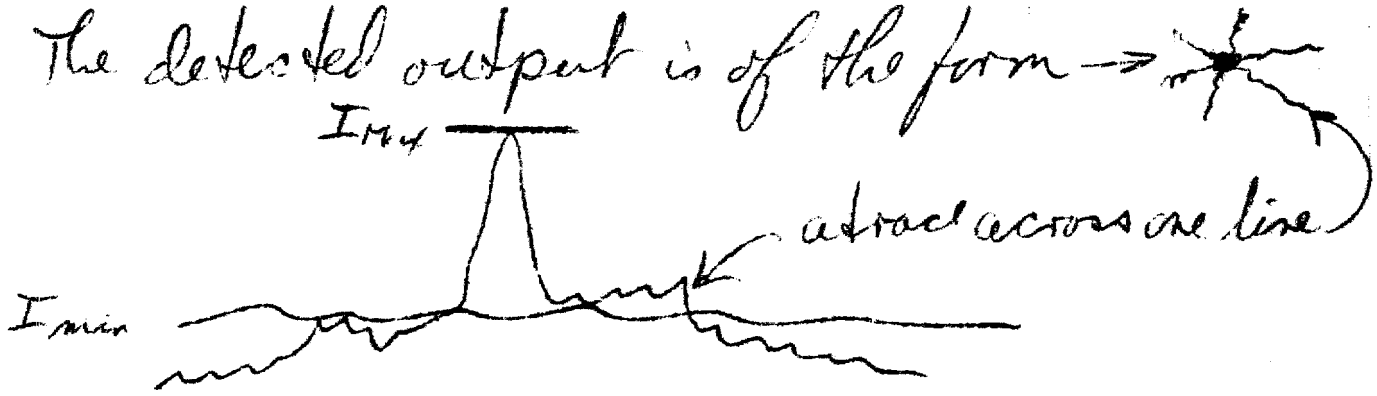
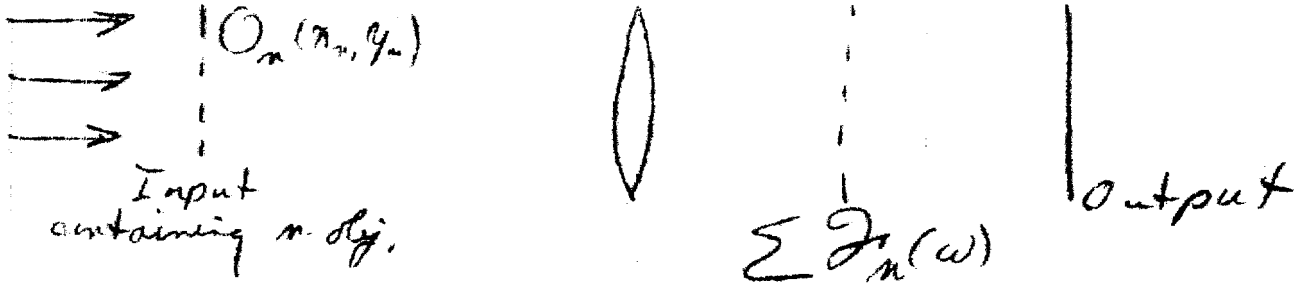
The detected output is of the form →



The greater Imax is with respect to Imin, the greater the correlation between the input target and the detection filter.

We get the central peak from a smoothed function. Consider the system



The transform plane contains a complex summation of the Fourier transform of all n objects on the input format. We place in this plane a filter matched to one of these objects, the one we want to detect presence of, say object #3 O_3. The filter is $\mathcal{F}_3(\omega)$. What occurs is as follows:—

The filter smooths out the energy (and only that) of object #3 & other equal objects (equal in shape). This occurs by the following example:—

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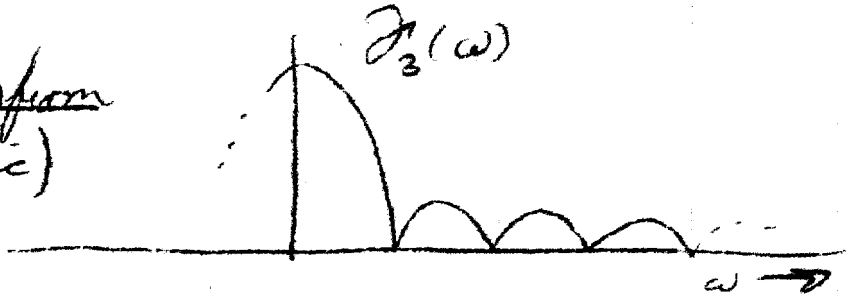
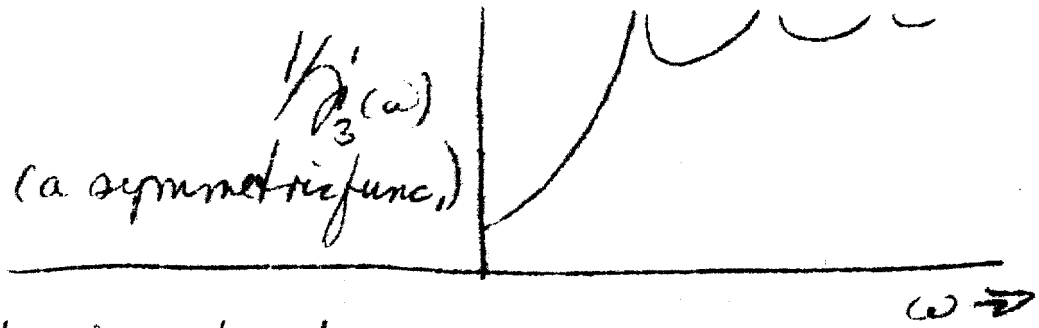
Example

1 input object #3 $O_3(x)$

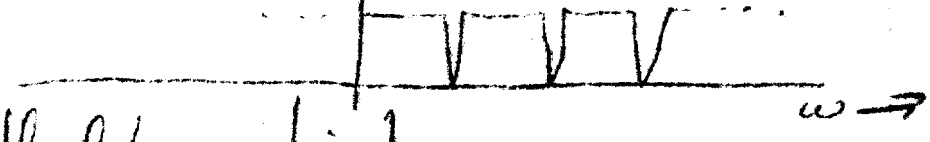
2 its transform (its symmetric) $\mathcal{F}_3(\omega)$



3 the filter $1/\mathcal{F}_3(\omega)$ within limits (i.e. ∞ cannot exist) $\frac{1}{\mathcal{F}_3(\omega)}$

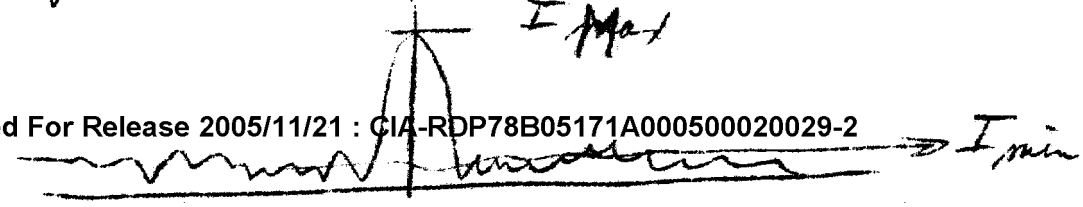


4 filtered output at the filter plane $\mathcal{F}_3(\omega) \cdot \frac{1}{\mathcal{F}_3(\omega)}$



a smoothed function!

5 output of detection system $P(x)$



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Subject

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The more closely any object approximate the filter, the higher the correlation output Detection is performed at the output & determined by the correlation level (the intensity peak level). Objects not related to the filter are aberrated by it and no correlation is found at the output.

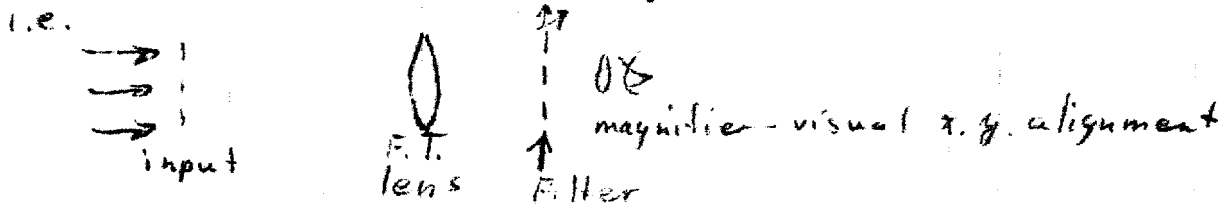
Alignment of filter & input object for test.

We start with an aligned bench as previously directed (see p. 8 ff.)

1. Set target in object (input) plane of processor. Use only the test target for this portion of the procedure. (Here we want to measure filter value, not apply it. This is a calibration procedure.)

2. Set hologram in filter plane. Align directionally as it was fabricated.

3. With magnifying eyepiece align filter in x & y with the diffraction pattern of input object.



4. Rotate input transparency to align its diffraction pattern with filter.

5. We look at output of detector

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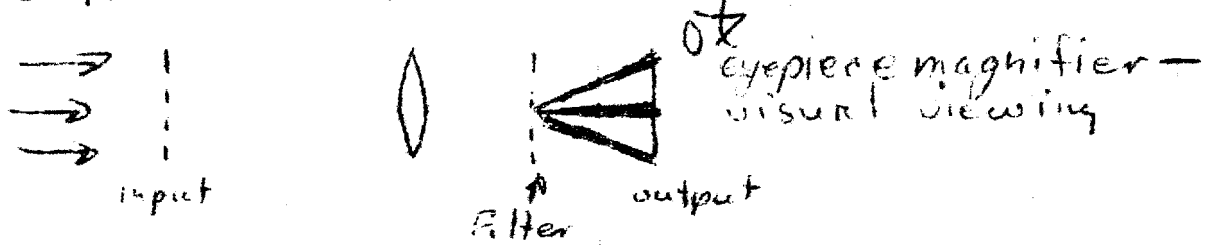
as illustrated.



Repeat x, y alignment and ⊖ alignment. THIS IS THE FINAL CHECKOUT — IT OPTIMISES THE OUTPUT — OPTIMUM ALIGNMENT IS THAT WHICH GIVES OPTIMUM SIGNAL OUTPUT.

⇒ Test of results with different targets + filters
Other sampled outputs include the following targets.

Photograph of detected output where input is two triangles

△
▽

Note this result + compare it to that shown on page 21.

The off axis term on the right contains the signal term as the one on p. 21. However the triangle that is now present is the mirror image of the 1st and its signal output is to the left. Why? See next page.

Conjugate term ↑ dc term ↑ signal term ↑

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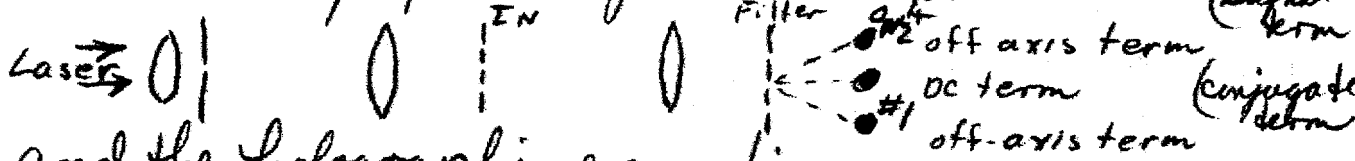
Explanation of phenomen photographed on page 25.
Note the holographic system output

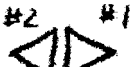


and the holographic equation

$$\underbrace{K^2 + |A(\omega,\nu)|^2}_{\text{dc term}} + \underbrace{KA(\omega,\nu)e^{-i\alpha(\omega,\nu)}}_{\text{off-axis \#2 term}} + \underbrace{KA^*(\omega,\nu)e^{i\alpha(\omega,\nu)}}_{\text{off-axis \#1 term}}$$

Note that the off-axis terms are complex conjugates of each other.

Now consider the two triangles



Let $g(x,y)$ describe #1, then triangle #2 is described by $g(-x,-y)$. Then

$g(x,y) \leftrightarrow G(\omega,\nu)$ are Fourier transform pairs

$$G(\omega,\nu) = \iint g(x,y)\, e^{-i2\pi(x\omega+y\nu)}\, dx\,dy$$

and

$g(-x,-y) \leftrightarrow H(\omega,\nu)$ are Fourier transform pairs

$$H(\omega,\nu) = \iint g(-x,-y)\, e^{-i2\pi(x\omega+y\nu)}\, dx\,dy$$

let $\alpha = -x$, $\beta = -y$

$$H(\omega,\nu) = \iint g(\alpha,\beta)\, e^{i2\pi(\omega\alpha+\beta\omega)}\, d\alpha\,d\beta$$

$$\boxed{H(\omega,\nu) = G^*(\omega,\nu)}$$ Complex conjugates of each other.

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Therefore, when the two objects are related as

$g(x,y)$ and $g(-x,-y)$

Fourier transform pairs ↕ ↕

$G(\omega,\nu)$ $G^*(\omega,\nu)$

their Fourier transforms are complex conjugates of each other. Thus their outputs in the hologram detection system are complex conjugates — causing signals to appear at opposite off-axis points.

Other targets and detected outputs are

Photo located here!

This target of 3 triangles was hand aligned. Slight errors of alignment are noted at the detected output. Note the conjugate image noise —

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The previous results were obtained using a filter described on p. ___ that was obtained on the interferometer with a 4 sec. exposure. Test of an 8 sec & 2 sec. exposure filter (all other conditions remaining the same) are shown here.

Photo located here

Test output for 8 sec. exp. filter

Photo located here

Test output for 2 sec exp. filter.

8 sec exposure filter appears with more signal selectivity & less noise than 4 sec or 2 sec filter.

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Results up to this time are encouraging. We must now emphasize refinement of filter fabrication system and techniques, detection system, targets to demonstrate system operation and data display (records of results). Targets must be designed for optimum description of system intent and value of detection by optical techniques.

May 11, 1970

[redacted]

The schedule for [redacted] lab includes May 11-13 with [redacted] on 11-12 May, [redacted] on 12-13 May and for some interaction on 14 May.

a.m. Discussion

We updated the situation on this program with a discussion on several relevant points.

1) What do theoretical assumptions have to offer to laboratory experiments? This subject will be brought up during the lecture series to evaluate the significance of all assumptions. Often they are made to only on a mathematical basis - and although the specified limits define an operational range for the experiment these limits may also be more rigorous than experimentally required. Among such assumptions are far field approximation + the Gaussian beam.

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Date May 11, 1950

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2. A target was made up by John C, containing a number of different objects. We will use it for target detection demonstration. It looks good.

Photograph of "target detection" target located here,

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3. Program direction for this week
   a) Interferometer
      i alignment
      ii focus of output
      iii manipulation of amplitude of reference wave to center fringes at higher frequency portions of signal target diffraction pattern.
      iv longer exposures of target diff. pattern to gain higher frequencies for high pass filt. and better target discrimination.
   b) Coherent Image Processor
      i alignment
      ii TV vidicon camera for monitoring output
      iii capability of hard copy output
      iv film process for S/N measure of detected signals.

INSERT ▼ Film process for filter $\gamma = 2$
Process for $\gamma = 2$ Microdol X Straight 5 min
DK 50, 1 part to 4 parts H_2O
5 min
Kodak microfile film

To Lab
Tasks performed
1) Checked alignment & focus of output recorder. Cleaned up reference beam.
2) Photographed hologram output of Δ.
   Series 1) 0.4 ND in ref. beam
   2) 0.0 " " " "
   3) 0.8 " " " " by two passes through 0.4 N.D.
   4) Processed in DK 50
   Exposure times 1 sec to 60 sec
   1, 2, 4, 8, 15, 30, 60

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5) Microfile film was processed to $\gamma \& I$ 2 with DK50, 1 part to 4 H_2O for 5 min. Note that ideally we should try for $\gamma = 2$.

p.m. During the afternoon the lecture series #2 was conducted.

May 12, 1970 STAT

STAT a.m. lab [redacted]

Placing hologram filters into coherent image processor for checkout.

For processing to proper gamma note

(a) output of interferometer is

$$K e^{i\alpha} + \mathcal{F}(\omega, \nu)$$

where $\mathcal{F}(\omega, \nu)$ is Fourier transform of function for which filters desired.

(b) Film at interferometer output responds to intensity

$$T_I = E^{-\gamma}$$

T_I = film intensity transmittance

$E = I \cdot t$

T_A = film amplitude trans.

$$T_A = T_I^{1/2}$$

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let t (exp. time) $= 1$

$$T_A = T_I^{\gamma/2} = I^{-\gamma/2}$$

note that $I(\omega,\nu)$ is the intensity output of the interferometer.

$$I(\omega,\nu) = \left| Ke^{i\alpha} + \mathcal{F}(\omega,\nu) \right|^2$$

$$T_A = \left\{ \left| Ke^{i\alpha} + \mathcal{F}(\omega,\nu) \right|^2 \right\}^{-\gamma/2}$$

$$T_A = \left\{ |K|^2 + |\mathcal{F}(\omega,\nu)|^2 + Ke^{-i\alpha}\mathcal{F}(\omega,\nu) + Ke^{i\alpha}\mathcal{F}^*(\omega,\nu) \right\}^{-\gamma/2}$$

if $\gamma = -2$

$$T_A = \left\{ \text{DC terms} + Ke^{-i\alpha}\mathcal{F}(\omega,\nu) + \text{conjugate term} \right\}^{-1}$$

the inverse filter $\therefore$ $\boxed{T_A = \frac{1}{K\mathcal{F}(\omega,\nu)}}$ at the $e^{-i\alpha}$ term

Therefore $\gamma = +2$ for the inverse filter. (the negative)

For the matched filter let $\gamma = -2$ (reversal process)

Then we have

$$T_A = \left\{ |K|^2 + |\mathcal{F}(\omega,\nu)|^2 + Ke^{-i\alpha}\mathcal{F}(\omega,\nu) + Ke^{i\alpha}\mathcal{F}^*(\omega,\nu) \right\}^{+1}$$

the matched filter $\boxed{T_A = K\mathcal{F}^*(\omega,\nu)}$ at the $e^{i\alpha}$ term

if $\gamma = -2$,

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Testing of detection filters formed on 11 May 1970.
Results

(a) First of all we should have processed them to $\gamma = 2$ rather than $\gamma = 1$.

(b) On a quick test basis we found that the filter with the 0.4 ND in the reference beam provided best results — greatest diffraction energy — best S/N ratio. This was photographed on 3000 ASA Polaroid and is placed here.

Photograph located here.

Detected output using a 4 sec. exposure of the interferometer output - & a .4 ND filter in the reference beam. Filter fabricated on 11 May 1970.

This photo contains DC noise (to left) and detected output to right. Note that bright central peak occurs to the right

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two filters exposed on interferometer
(a) of triangle
(b) of airplane
onto microfile film — processed to $\gamma = 2$ DK 50 2:1 5 min
exp. time
1/4, 1/2, 1, 2, 4, 8 seconds
using 0.9, 0.8 and no ND in reference beam.
These filters were tested and photos of output of best triangle were taken & are mounted below.

low exposure of output

Photo here

(1) Note that dc term is to left — detected output to right.

(2) Note that center of detected output is a bright peak.

medium exp. of output

Photo here

Detected output of filter fabricated on 12 May. DC term to left, detected signal to right.

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1. Up to this time all filters have had a mottled beam — and this mottling can significantly delete filter effectiveness.
2. The airplane filter fabricated on 12 May a. m. looked to contain only low freq. info. Test was therefore not applied.
3. The interferometer was cleaned up again to get rid of the mottling + new filters exposed.

May 13, 1970

STAT

STAT John C & [redacted] in the lab.

The filters of the airplane will be checked out this A.M.

System conditions when filters were made —

(1) Simple 10" focal length coll. lens which gave a cleaner beam than the 446 mm lens.

(2) Air turned on

(3) 1st set of exposures 1 sec. – 32 sec. with ND = .8
2nd " " " 1 sec – 32 sec, 1-2-4 min. " = 1.4

ND in ref. beam. – This may be the cause of the mottling

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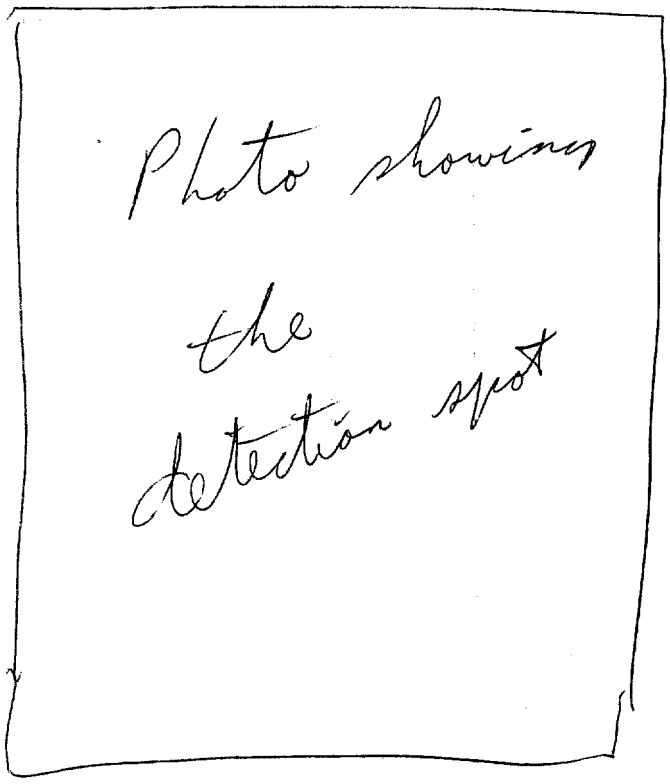

Filtered result of the airplane

The filter used was 32 sec exp. with a 1.4 ND in the ret beam.

Exposure time of the print above was 1 1/2 min.

Note: The laser on the processor is only 1 m.w. output
∴ the long exposure.

Also note that the frequency of the filter has increased.

Any exposure using a filter of 16 sec gave better results than that shown above.

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DC Term →

Photo of detection signal, with the target as shown on page 30

← Detection peak.

Detection of the airplane in the total target shown on page 30. The maximum peak is in the lower left.

Note the following:

(1) The signal has very little noise

(2) The other 3 bright spots have a large noise factor

(3) The frequency of the fringe is very high as can be seen by the separation of the DC term and the signal spectrum.

(4) The DC term and the signal spectrum does not focus at the same plane. The DC being at a further distance.

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Student's Name [redacted] May 13, 1970

Subject

Instructor's Name [redacted]

STAT John C [redacted] P.M.

(1) Find the best filter (for detecting the airplane) that was generated on the 12th; this should give us the best exposure time and the amount of ND to insert in the ref. beam of the interferometer.

(2) If time permits start making new filters of other targets using a high contrast target - this will give us good high frequency filters.

(3) Change the angle on the interferometer to lower the frequency.

(4) Remove ND for at least 1 exposure to see if the mottling remains or is deleted.

Photo of detection peak, with the image plane focused on the DC. spot.

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Detection result with the DC term focused
Note this result is better than that on Page 38

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which was optimized for best focus of the detection peak.

Answers.

(1) Best Filter

The best filter was the one used for the results shown on pages 38 & 39.

32 sec. exposure
ND = 1.4 in ref. beam

Note: With an ND = .4 no results were found.

(4) ND + mottling

The .4 ND used in the ref. beam was very dirty although I do not think is the the complete answer.

(3) The angle of the ref. beam was changed to decrease the frequency.

(2) A high contrast target will be used this time

Scene aircraft
1st exp. ND = 1 exp 8 sec – 1 min
2nd " " = 1.3 " " "
3rd " " = 1.6 " " "
Transform alone 40 sec.
Ref. alone 1 sec

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John will develope the film and check the filter for the best N.O. in the ref beam

---

grace m

Filter test series

May 19, 197

STAT

Additional changes in the two interferometer variables were made to obtain improved filter characteristics. These variables are

a) Exposure to Fourier transform of target (where increasing exposure records higher frequency information that has lower energy level)

b) Amplitude of the reference beam (so that it is matched with the signal beam for maximum modulation at the higher frequency components of interest.)

For details regarding exposures taken see D C notebook.

Test results are shown on next page.

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Filter of larger arrow. See format of input beam on p. 30.

1. 8 sec. exp. of F.T.
NO 2.0 for ref. beam

Photo here

Note that the correlation and conjugate outputs are similar. Filter has no selectivity.

2. 60 sec. exp. of F.T.
NO 2.0 for ref beam

Photo here

Very good selectivity.

3. 60 sec. exp. of F.T.
NO 1.6 for ref beam

Photo here

Very good also!

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At this point we can conclude continuing experimentation and put together demonstrative evidence that the system is functioning well — and that it is applicable to image manipulation (restoration etc.) as it is to target detection.

However we still need a higher power laser for active demonstration. For the time being we can record data on film and have pictorial outputs.

Requirements

1. Demonstration target examples (c/f p 30)
2. Operational type material.
3. Target restoration input.

With these three inputs we can demonstrate significance of operation and its utility as an operational set-up. It provides the easiest method of fabricating analog complex filters.

Discussion

To efficiently obtain the above requirements we will perform the following:-

(1) Fabricate several target detection filters from objects recorded on the demonstration target (p. 30). Record the detected output on film and make prints to demonstrate selectivity of filter, what clipping will do, etc.

(2) Perform the same for simulated or available operational type material. Obtain a format where there is some imagery with detail — boats or planes etc. Show selectivity of filter to detect specific types.

(3) Fabricate a blurred image using a pendulum for the motion source (fairly constant). Make a target that is binary, has points within the format. This target

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is intended

Note the processing requirements

1. We saw that the hologram detection filter should ideally be processed to $\gamma = +2$. This is to obtain an <u>inverse filter</u>.

2. For the imagery that we fabricate for detection purposes we have ...

a) intensity trans. of film $T_I = I^{-\gamma}$

b) when its placed into the coherent system we want to consider amplitude trans.

$$T_A = I^{-\gamma/2}$$

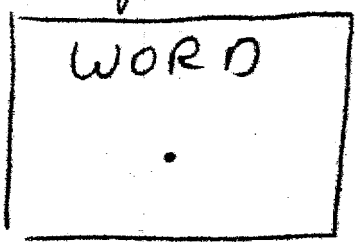
c) for linearity between T_A and I we require

$$\gamma = -2$$

then

$$T_A \simeq I.$$

We could use a target designed as:



The target is binary, the dot image can be used to fabricate the [illegible] filter to restore the blurred format. That is

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The scene has an intensity distribution —

$$I(x, y)$$

The image of the scene is given by

$$I(\alpha, \beta) = I(\alpha, \beta) \circledast S(\alpha, \beta)$$

where $S(\alpha, \beta)$ is the imaging system point spread function. If the scene is aberrated then we can say that the aberration information is contained in the point spread function. For example,

① object intensity object

② good point spread function 'good' point spread function

③ image of ① + ② is

① ⊛ ② → 'good' image

If the point spread function is blurred and can be assumed as

④ blurred point spread function Smeared point spread function

then the blurred image is

① ⊛ ④ → Blurred image output

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Therefore it is correction of the point spread function that gives us a corrected image. ⇒ Note that the correction filter is exactly similar to the detection filter we essentially get from the blurred point spread function!

a corrected point spread function

which when convolved with the object intensity means we have a corrected image output.

We should be careful to use correct gamma processing — and to use input functions to the system to gain optimum signal for the filter.

Note that for image restoration we can process the format (shown on p. 44) to a $\gamma = +2$ (a negative) and then dupe this to $\gamma = -1$. That way we'll have both a $\gamma = +2$ and $\gamma = -2$ to apply for the filter and the transparency respectively

---

To obtain good prints of the output we need to photograph the output on film. Used Par-X film — 3 sec exp on f8 for the large arrow filter. John has these negatives.

Blurred targets were prepared for the demonstration of image restoration on the holographic breadboard. We use a format similar to the design illustrated on p. 44.

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Student's Name

May 20, 1970

Subject

Instructor's Name

7:45 am Task of the day —

1. Prepare imagery to demonstrate target detection on operational type material
2. Prepare imagery for image restoration demonstration.
3. Fabricate additional filters for detection of targets on the lab prepared format (see p. 30).
4. Collect filtered output onto 35 mm. film
5. As time is available, print up results.

These five points are directive that effect through to completion of this phase of the program.

Effort during a.m.

Photographing filtered output of twin boom aircraft and of large arrow. We found that the Pan X used on 5/19 was faster than Recordak.

also recorded hologram filters of

a) plane from operational material
b) ~~arrow~~ (the largest star on special target)
c) plane (rect. beam on special target)
d) smear impulse
e) plane from operational material

all recorded on Recordak.

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p.m. The results are:-

→ star and plus from special target look excellent. The others are marginal. They do not record sufficiently high frequencies beyond the resolution of the system.

What makes a good filter?
There are several understandable (common sense) parameters that aid one to determine, prior to testing, whether a filter is good. First, note that the central diffraction spot of the spectrum of all objects are very similar. Therefore the filter that contains only this portion of the spectrum will not detect one object from another. Only a filter that contains spectral information significant to the object will be able to uniquely detect that object from others. This occurs at higher frequencies. Second, the reference beam amplitude must be balanced with the transform so that interference occurs at the region of the diffraction pattern that is significant to the object to be detected. Third, the greater the selectivity property desired, the high the frequency of the filter required.

Refer to the Program Plan dated 20 May 1970 for specific details in direction for the next week.

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Student's Name May 25 1970

Subject Linear Motion

Instructor's Name

John made a target LINEAR MOTION and gave it linear motion of .4 mm. With this amount of motion it is not possible to read the words.

This morning will be used to make a filter for the above target.

1. John tried to make a filter last week without ~~a~~ No results were obtained since the energy was too low.
   A new slit is being used with the following .4 mm long and 50 μ wide.
2. ND of ___ was placed in the ref. beam since the energy is so low in the signal beam.
3. Pan X is used in this case to find the proper exposure
   expo times 1 min – 3, 6, 12, min.

   A one min exposure time is long enough for recording the signal and ref beam.

   A close look at the results show that the signal did not have enough energy.

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John + Dick

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Student's Name

Date May 25, 1970

Subject

Instructor's Name

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Recording motion filter on microfill film

The mirror of the ref. beam was changed so a larger format is obtained, the angle is also smaller and thus the frequency is lower.

Exp. Times 1, 1⅓, 4, 12 min

all these exposures were too short.

New exposure times

24 min and 1 hr.

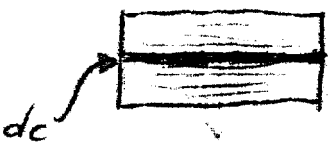
These exposures were also too small

Note

Although a narrow slit is needed for high resolution a wider slit is needed to obtain enough energy to record the transform.

A trade off may be needed so the following will be tried.

1. the width of the slit controls the length of transform DC spot



35mm format

The width of the slit will be set so that the 1st zero of the transform will just touch the edge of the reference beam.

John + Dick

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Student's Name Approved For Release 2005/11/21 : CIA-RDP78B05171A000500020029-2 May 25, 1970

Subject

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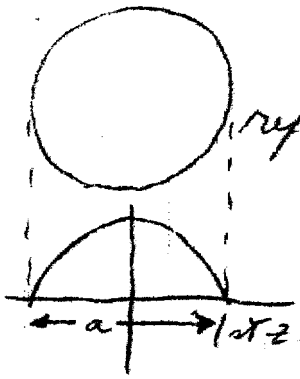
2. The length of the slit will be set at .4 mm.

STAT

May 26, 1970

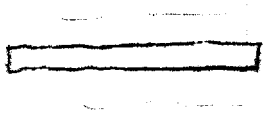
AM

Using the Spindler & Hoyer slit, John opened the slit until the 1st zero or the transform was at the edge of the ref. beam.



The length of the transform a is controled by the slit width

The length of the slit when set at .4 mm shows only the d c in the transform plane, for this reason a larger slit length will have to be made.

 } transform of the slit

The energy is too low to record the transform.

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John + Dick

STAT

Student's Name Approved For Release 2005/11/21 : CIA-RDP78B05171A000500020029-2 May 26, 1970

Subject

Instructor's Name

Steps to Take:

1. John will photograph* the target ("Linear Smear") with a smear distance of about 2.5 mm.

2. I will set the slit on the transform recording system to match the smear distance and set the width for maximum energy without loss of resolution.

* Note: γ control for the target will be used here.

$\gamma = +2$ on a file film

10K50 to 2 H_2O 2½ min @ 68°

Copy onto a file and develope for $\gamma = -1$

$\gamma = (+2)$ $\gamma = (-1) \Rightarrow \underline{\gamma = -2}$

for -1 Microdol X 5 min
or DK50 (1) to (4) H_2O for 5 min

PH

1st series of exposure of slit

ND = 2 in Ref beam 1 sec, 15 sec, 1 min, 2, 4 min

ND = 2. (Light?) " " " " " " 8 min

ND = ____ (Dark) " " " " " " " "

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Student's Name May 26, 1970

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Instructor's Name

Recording Target in motion

Exp Time	f/no	Smear Dist.
7 sec.		2.3 mm
7		"
7		"
8		2.5 mm
8		"
8		"
9		3.0 mm
9		"
9		"

Over Exposed

New Exposure Series

f/5.6 → f/22

John 6 hrs.
Dick 8 hrs.

7 sec, 8 sec, 9 sec exposures

May 27, 1970

AM

1. Develope exposures of motion pictures taken last night
2. Copy onto a file $\gamma = -1$ 5 min DK 50
   4 parts H_2O, 1 part DK 50
3. John is having prints made
4. John when done with prints will reconstruct the slit to check the best filter.

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Student's Name STAT Date May 22 1973

Subject

Instructor's Name

Best exposure

Contact Print for $\gamma = 1$

Exp Times 1 + 2 sec. 2 sec looks good

Next Series 2, 2½, 3 sec. exposures

Good exposure is about 2½ sec.

Reconstruction tried on bench but no results were obtained.
The only explanation at this ~~this~~ time is the smear distance and length of slit used for the filter were not matched.

PK = a new set of filters are being made with a slit from one of the smeared scenes.

ND = 2 Ref beam Exp. Time = 1, 15 sec, 1 min, 2 min, 4 min

ND = 2. ___ " " " " "

ND = 2. ___ " " " " "

→ Best exposure series

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STAT

Student Name

Date May 27, 1970

Subject

Instructor's Name

Using the one min exposure the following result was recorded.

Photo of Reconstruction

The smear that was present in the original target as shown below has been removed as can be seen in the above photo. Note that the horizontal word in the dc above in not in the format of the coherent beam of the processing system.

Neg of smeared target

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Student's Name

May 27, 1970

Subject

Instructor's Name

System Problems

The laser on the coherent processor is only delivering 1 mw (it is a 10 mw laser). For this reason a small imaging collimated beam is used to conserve the light we do have. Since this beam is small it will be necessary to filter a single word at a time. Below is an example showing both words. These words are on the edge of the Gaussian intensity distribution and thus poor results although it is readable in the vertical direction.

(Photo of reconstruction)

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Student's Name STAT

Date May 27, 1970

Subject

Instructor's Name

alignment of filter.

The present system has x, y and z control on the filter and x, y, z and rotation on the target. In order to align the filter in rotation the object plane has to be rotated and thus requires two people. At this time it will be nice to have a rotatable stage in the filter plane. It is understood that as the filter is rotated it has to be readjusted x-y unless it is mounted on the exact center of the rotatable stage. Although this is inconvent it only requires one person to align the filter.

John was tied up most of the day with making prints and working on a report so today's effort was mainly my own.

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Student's Name [redacted] Date 27 1970

Subject

Instructor's Name [redacted]

Next steps to perform using coherent processor

1. Center each word of the object in the coherent beam so that maximum energy is passing through the target.

2. Try several of the filters made and choose the best for linear motion correction.

3. If time permits it would be nice to make several new filters with the following parameters

   a. keep width constant vary length

   b. " length " " width

   C. after using the above make a third set of filters with some combinations varying around the best filter.

4. Judgements can now be made about the variations in filters VS smear correction.

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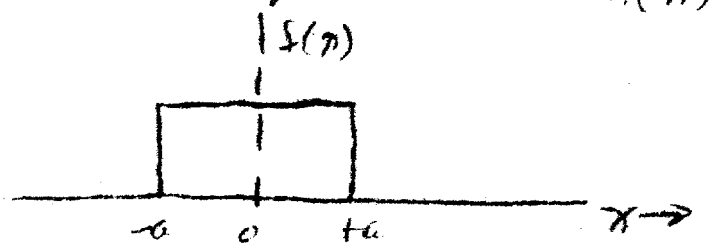
Student's Name June 3, 1970

Subject Instructor's Name

Analysis of smeared image (see p 55.)

Smear function $S(x) = R[x/a]$



Frequency response is Fourier transform of point spread function.

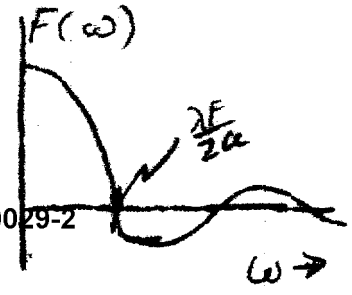
$$\tilde{F}(\omega) = \int_{-\infty}^{\infty} R[x/a]\, e^{i\frac{2\pi\omega x}{\lambda F}}\, dx$$

$$= \int_{-a}^{a} e^{i\frac{2\pi\omega x}{\lambda F}}\, dx$$

$$= \frac{e^{i\frac{2\pi\omega a}{\lambda F}} - e^{-i\frac{2\pi\omega a}{\lambda F}}}{i\frac{2\pi}{\lambda F}}$$

$$= \frac{\sin\frac{2\pi\omega a}{\lambda F}}{\frac{\pi\omega}{\lambda F}}$$

$$= 2a \operatorname{sinc}\frac{2\pi\omega a}{\lambda F}$$



first zero at $\frac{\lambda F}{2a}$

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Student's Name

Date 3 June 1970

60 STAT

Subject

Instructor's Name

Consider the smeared function on p. 55 —
the line spacing of the letter 'a' ≃ 0.045"

a spatial frequency of

$$\frac{1}{0.045}\ \ell/\text{in} = 22.2\ \ell/\text{in}.$$

the smeared function f(x)

$$2a \simeq 0.09"$$

$$\frac{1}{0.09}\ \ell/\text{in} = 11.1\ \ell/\text{in}$$

Frequency response zeroes occur at

11.1, 22.2, 33.3 etc ℓ/in.

Therefore the letters of this target are a good demonstration of information lost because of image motion blur.

Note - measurement of distances taken with 6X magnification comparator ——.

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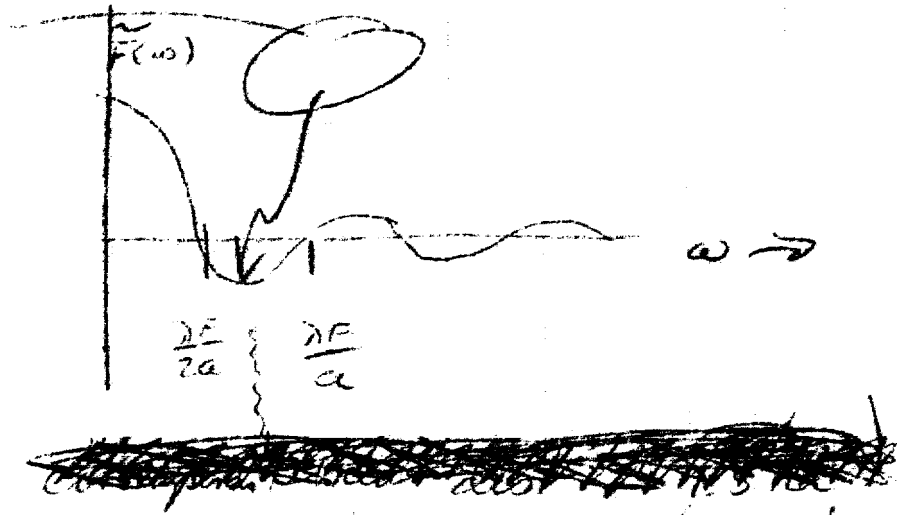
Student's Name 3 June, 1970

Subject Instructor's Name

We should design a demonstration of image blur — want info to be spuriously resolved — want frequency response to be high — aim scale at this region



if a = 0.045" (characteristic letter width, then we want a smear distance such that the first frequency zero occurs at 14.7 ℓ/in.)

Want 22.2 ℓ/in to occur at peak of second lobe.

$$= \frac{1.5}{2a} = 22 \text{ ℓ/in}$$

$$\frac{1}{2a} = 14.7 \text{ ℓ/in}$$

Want a smear of approx. 0.07 in.

$$2a = \frac{1}{14.7} \text{ in} \approx 0.07 \text{ in}$$

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Student's Name 25X1 Date 3 June 1970

Subject Instructor's Name

We now need to photograph additional smeared imagery ——— first we are to evaluate the filters fabricated on 5/27/70.

1. Looking at filter #2 output, optimizing the m while viewing ———

Photo located here

2. To check the filter #1 we looked at its response to the smear function from which it was made!

Photo located here

Note peaked output — as would be expected from a good filter. This shows analogy between target recog. and image restoration

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Student's Name [redacted] 3 June 1970

Subject Instructor's Name [redacted]

Purpose of these photos is to evaluate effectiveness of filters. From the last photo we can see that a sharp peak output can be gained. To get a clear image output the following photos were taken ——. Note the point function output

Photo located here

Filter #2

Photo located here

Filter #2

When the imagery is not coming through it is because of:

(1) The frequency of the letters is near or at a null of the letter frequency response

(2) The image is exposed for visual or too low + info is lost because of the film response.

(3) Blur is large compared to image scale and frequency resp. is very low.

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Student's Name

Date 3 June 1970

STAT

Subject

Instructor's Name

(4) Nonlinear recording of function (image function).

What we should do is look at different kinds of smeared images — to the scale of one of the filters that we have available.

4 June 1970

Further attempts to use image smear compensation filter to restore a blurred image.

Photo located here

Fitter #2

1½ min exp
ASA 3000

same but ½ min exp.

photo located here

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Student's Name 4 June, 1970

Subject Instructor's Name

We are being severely limited by low output of laser. It is impossible to view some of the targets — and therefore refinement of filter alignment cannot be done.

An enlarged scale of target was ordered so that smear is small relative to letter size. 1/ An aberrated diffraction spot was always present in the transform plane & the filter could not be aligned —

2/ The energy was too low to visually monitor the filtered output and so the most important method of analysis was absent.

Therefore returning to previous targets to conclude checkout of filters —

a) using target from which filter was fabricated.

b) carefully aligning filter

a) 30 sec exp

ASA 3000 film

Photo here.

b) 40 sec exp.

Photo here.

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Student's Name

Date 4 June, 1970

Subject

Instructor's Name

Now looking at output (enough energy to see something with this target) and adjusting ~~target~~ filter to optimize output we get... Only norm used was to get symmetry for 'm'.

Photo here

Photo here

Photo here

Photo here

Photo here

These are representative of what can be obtained from the present components.

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Student's Name

Date 4 June, 1970

Subject

Instructor's Name

Objective now is to complete with best results that can be obtained in the next week. To do:—

1) The filter that we have is not completely symmetric. We should try to re-expose using a slit function input to the holographic system.

2) Make up a couple of targets to show reconstruction ability with several inputs.

These two objectives were related to John C. on 5 June at 10 am through Dennis R.

---

9 June 1970

Target Recording

Smear Target

Exp. Time	f/no.	Smear Dist.
7 sec	5 6	
8 sec	8	
9 sec	11	
	16	
	22	

Best recording in f/16 and f/22

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Student's Name _____ Date June 9 1970

Subject _____ Instructor's Name _____

"Number" Target Horizontal

Exp. Time	f/no
4 sec.	11
6	16
8	22

~~Format to large~~
Numbers readable

Res. Target

Exp. Time	f/no.
7 sec.	11
8	16
9	22

~~Format Is large~~

f/2 - 7 sec. = 2.5mm smear

"Number" Target Vertical

Exp. Time	f/no
7 sec.	16
8	22
9	

2, 2.4, 2.6 mm smear
2, 2.5, 2.6 mm smear
~~2, 2.5, 2.6 mm~~

"[illegible]" Target

Exp. Time	F/no
7 sec	16
8	22
9	

f/16 2, 2.4 2.6mm
f/22 2, 2.5, 2.6mm
Format To large.

Ned

Word "TEST" Target

Exp. Time	F/no
7 sec.	16
8	22
9	

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Student's Name [redacted] Date June 9, 1970

Subject

Instructor's Name [redacted]

Smear Filters

Exp. Times 1, 15 sec. – 1 min, 2, 4 min.

ND = 2.3 in Ref Beam

Spindler & Hoyer slit widths (mark on micrometer)

1st roll	15 ✓	.1	bandwidth of DC spot	length = 2.5 mm
	10 ✓	.128		
	5 ✓	.180		
	1 ✓	.279		
2nd roll	0 ✓			
	−1 ✓			
	−2 ✓			

} slows in ref beam (neutral density)

concluded above work 5:15 PM.

June 10, 1975

[redacted]

7:40 A.M.

Evaluation of the smeared targets made on the 9th shows that there are good exposures with a smear distance of 2.5 mm.

The filters photographed last night are being developed this morning. These filters have resolution values specified above as slit widths.

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Student's Name STAT Date June 10, 1970

Subject Instructor's Name

The best series of targets will be contacts printed this A.M. for a $\gamma = 1$.

The filters generated last night failed to give the required results:

1. The mirror moved on the interferometer
2. Vibrations caused the fringes to smear so (they were not recorded (air probably turned off — it was after 4 P.M.

PROGRAM ANALYSIS + REVIEW

At the start of this program we had directed the set-up and operation of the holography system with the intent that we demonstrate its operation by means of target recognition filtering. Therefore we made the filter ... with the amplitude transmittance

$$T(\omega) = \left\{ \left| K e^{i\alpha} + S(\omega) \right|^2 \right\}^{-\gamma/2}$$

processed to $\gamma = +2$ for

$$T(\omega) = \left\{ K^2 + |\tilde{S}(\omega)|^2 + K e^{i\alpha} S(\omega) + K e^{-i\alpha} S(\omega) \right\}^{-1}$$

(From the binomial expansion, $(ax+b)^{-1} = ax$ for low contrast.)

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$$T(\omega) \cong DC\text{ term} + K e^{i\alpha} S^*(\omega) + K e^{-i\alpha} S(\omega)$$

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Student's Name STAT Date 10 June 1975

Subject Instructor's Name

The term Ke^{ix} contains the complex conjugate of the signal term. Thus this is the matched filter for target recognition (no noise).

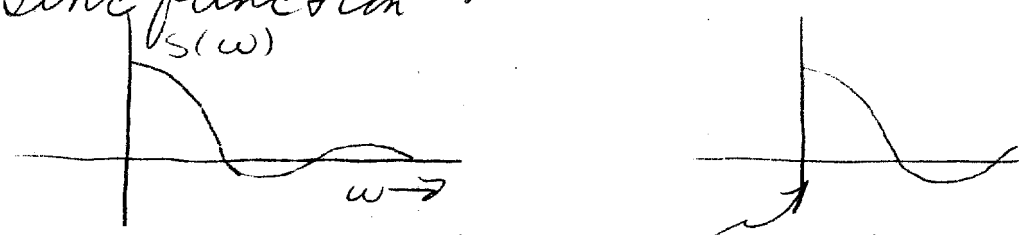
About mid-May it was suggested that we demonstrate the directional of the system relative to image restoration capabilities. We therefore used the technique for fabricating filters above to fabricate the same for [redacted]. But note that this is a matched filter whereas the best restoration filter is inverse. In image restoration the image can be expressed as

$$I(x) = O(x) \circledast S(x)$$

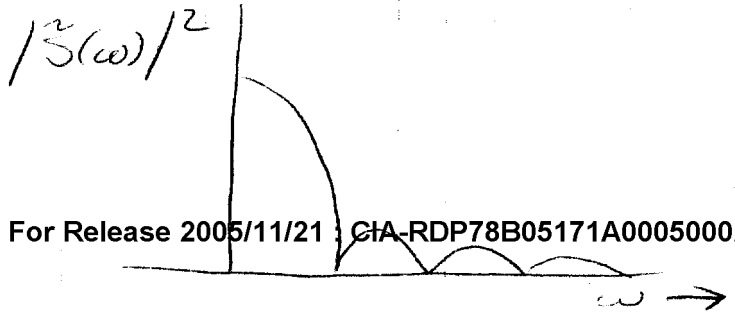
& in frequency space

$$\tilde{I}(\omega) = \tilde{O}(\omega) \cdot \tilde{S}(\omega).$$

For a blurred image (linear blur), $\tilde{S}(\omega)$ is a sinc function



The matched filter $\tilde{S}^*(\omega)$ is the same. Then $\tilde{S}(\omega) \cdot \tilde{S}^*(\omega)$ is



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Student's Name

Date 10 June 1970

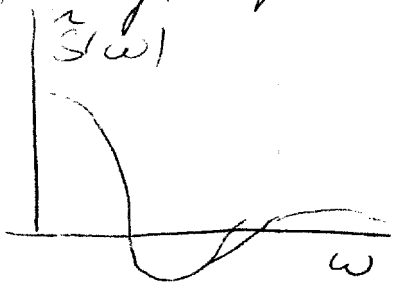
Subject

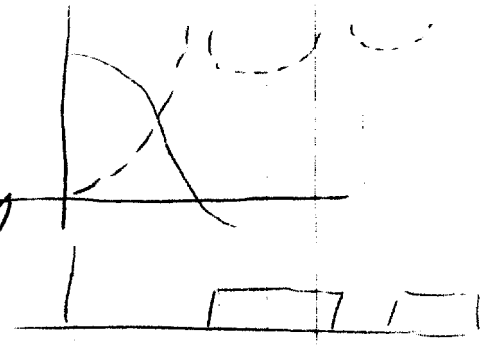
Instructor's Name

This is then the corrected frequency response of a matched filter is used. It will yield a corrected point spread function that is not sharp and narrow as one wants for image restoration.

The best image restoration filter is the inverse filter i.e.g. $1/\tilde{S}(\omega)$

the blur frequency resp. was $\tilde{S}(\omega) = \text{sinc}\, 2\pi\omega a$





the inverse filter is $1/\tilde{S}(\omega)$

with the result being a smoothed frequency response. The corrected point spread function is a sharp peak — so that the convolved output of the system is reconstructed (restored).

Reconstruction of #7 camera's with filter fabricated on 27 May, 1970. They looked

Reconstruction of #7.

Blurred image is on p. ——

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Student's Name

Date 1 June, 72

Subject

Instructor's Name

Checking out detection filters made on May 18th (they were not checked out — and we have been pushing restoration since then). Filters stored on Page 46 of John C. notebook. Refer to master target, pg. 30.

(1) Twin engine plane — filter is 'matched' output looks good

Photo here

exp time 1/15 sec

← detected output

photo here

exp time 1/125 sec

brightest output

Highest correlation at location of twin engined aircraft (although type of aircraft is similar).

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Student's Name Approved For Release 2005/11/21 : CIA-RDP78B05171A000500020029-2 Date 16 June 1970

Subject Instructor's Name

This filter shows excellent selectivity between the aircraft.
Another result at 1/8 sec exp.

Photo here

Now looking at the star matched filter made on 18th of May (see John C. notebook, page 46). This filter is not very good — (exposure or interferometer not long enough) because high frequency information not present on hologram filter.

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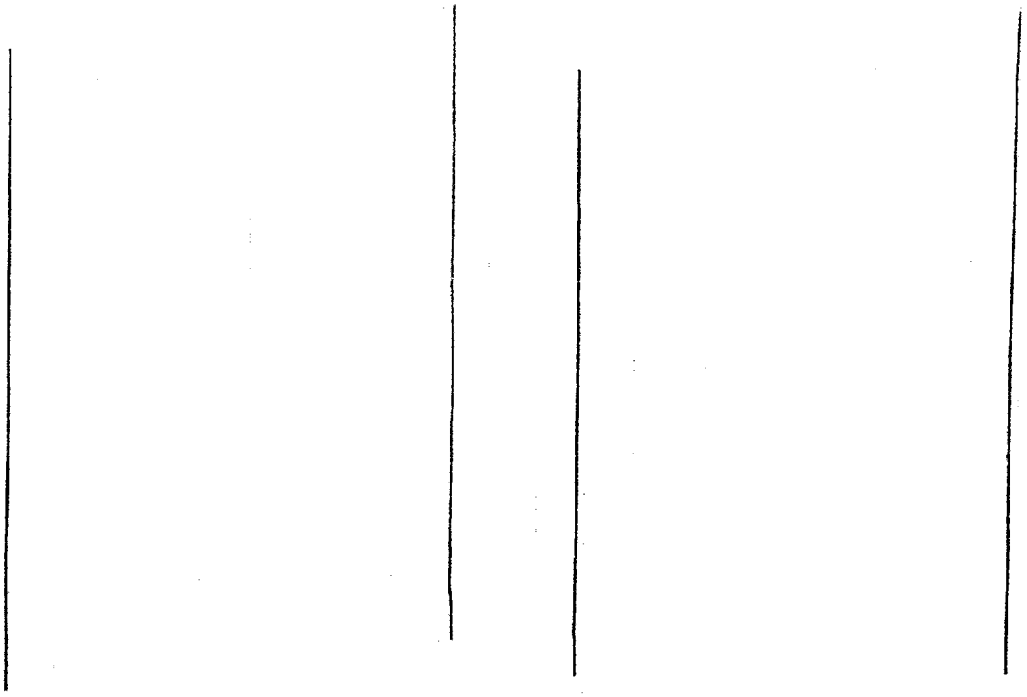
Student's Name [redacted] Date 11 June 1970

Subject Instructor's Name [redacted]

STAT

Some image blur restoration results obtained on 4 June, 1970 have been printed up. They are: —



Blurred image Restored image

Filter fabricated on May 27, 1970 by [redacted] Above setting was performed on 4 June by [redacted] Data on film prints made on 10 June in Lab.

STAT STAT

Go to Book No. 2 for continuing data records

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